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ABSTRACT

The study of science involves learning the processes of science as well as its content. The recent revival of interest in developing thinking skills has encouraged added emphasis on process skills instruction. A science teacher wanting to add instruction of process skills is faced with several problems: (1) texts and lab manuals are not likely to emphasize process skills; (2) time constraints; and (3) teaching style conflicts. The purpose of this study was to investigate the possibility of teaching process skills through a lecture-class discussion approach rather than a lab-activity centered approach. This approach was seen as valuable because it requires less time, fits the style of many teachers, requires fewer material resources and uses normally wasted class time. Two 10th-grade advanced first-year Biology classes at a Georgia high school were randomly selected for the study. The experiment, which involved two sections of advanced Biology from which one was to receive treatment and a second was a control group, was conducted over a 3-week period. The experimental data indicated that process skills can be successfully taught by the lecture-class discussion method. Students who were introduced to process skills by this method showed increased understanding of process skills with no loss of content achievement. This method of teaching was not seen as a replacement for process skills labs but as a way to introduce process skills instruction where it does not exist. (CW)

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INTEGRATING PROCESS SKILLS INSTRUCTION INTO THE TRADITIONAL SCIENCE CURRICULUM

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INTEGRATING PROCESS SKILLS INSTRUCTION INTO THE TRADITIONAL SCIENCE CURRICULUM

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Introduction

The study of science involves learning the processes of science as well as its content. The importance of science process skills instruction has been recognized for many years (Gagne, 1965). The recent revival of interest in developing thinking skills has encouraged added emphasis on process skills instruction. A 1983 update of the National Science Teachers Association position statement on science and technology stated:

> "The scientifically literate person has a substantial knowledge base of facts, concepts, conceptual schemes, and process skills which enable the individual to continue to learn and think logically." (NSTA, 1983).

While different educators have somewhat different lists of science process skills, the skills taught in the Science - A Process Approach (SAPA) curriculum (AAAS, 1965) are widely accepted. SAPA divides the skills into two groups: (a) the basic skills of observing, classifying, using space/time relations, using numbers, communicating, measuring, inferring, and predicting and (b) the integrated skills including formulating hypotheses, controlling variables, interpreting data, defining operationally, formulating models, and experimenting. Most integrated skills are composed of several basic skills. Experimenting will usually involve most of the other skills.

Several research studies have provided evidence that process

skills can be successfully taught. Shaw (1983) found that sixth grade science students taught with modules from Science - A Process Approach II curriculum scored significantly higher on the Objective Referenced Evaluation in Science (Shaw, 1982) than a control group which received content-only instruction. Peterson (1978) tested a secondary-level program to teach scientific inquiry, including process skills, to high school physics students. One treatment group received a verbal learning unit on scientific inquiry in addition to the regular curriculum. A second group received an activity-based program which involved the students in active inquiry. A third group served as a control and followed the regular Project Physics curriculum (Rutherford, 1970), including labs. Peterson found significant differences in the treatments as measured by a concrete materials manipulative assessment instrument. Increased scores were measured for both the verbal instruction treatment and the science inquiry treatment when compared to the traditional curriculum. The science inquiry treatment produced the greatest gains in the largest number of individual test items. Peterson concluded that the study supported the value of focused, specific training in scientific inquiry, as opposed to relying only on general science curriculum.

Padilla, Okey, and Garrard (1984) tested a model for teaching process skills to middle school science students. Two treatment schemes were compared with a control that received only content instruction. The treatment groups showed significantly higher achievement of several process skills than the control group.

The preceding studies have shown the need for supplementing the traditional curriculum with process skills instruction and the benefits derived from doing so. But a science teacher wishing to add instruction in process skills is faced with several problems. First, the available textbooks and lab manuals are not likely to emphasize process skills, especially the integrated skills. Even the newer science curriculum reform projects are not particularly successful at teaching science process skills. Heron (1971) found that the Biological Science Curriculum Study (BSCS) and the Physical Science Study Curriculum (PSSC) materials gave students little practice in using integrated process skills. Atash and Dawson (1986) performed a meta analysis of research evaluating the Intermediate Science Curriculum Study (ISCS) curriculum. Although they found a small positive overall effect (.09) for the ISCS student performance compared to performance of students in traditional science courses, the performance of ISCS students on the process skills variable alone was not significantly different from that of students taking the traditional science courses.

A second problem faced by the teacher trying to include process skills instruction in the science curriculum is time. Since most textbooks and other curricular materials available to the teacher lack adequate process skills instruction, teaching the skills will require additions to the current curriculum. If the curriculum now occupies all available instructional time, then finding time for the additional process skills material can present a real problem.

A third consideration when planning to add process skills instruction to the curriculum involves teaching style. Many teachers present much of their instruction through lecture and class discussion. Process skills are involved in laboratory performance and are often taught through lab activities, but lab skills and process skills are not synonymous. Shaw (1983) found that lab activities alone do not teach process skills. A teacher used to instructing through lecture and class discussion might be more comfortable providing process skills instruction in the same familiar format. Practice in using the process skills could then gradually be added to the lab program.

Purpose

The purpose of this study was to investigate the possibility of teaching process skills through an approach which was primarily lecture - class discussion centered rather than lab - activity centered. This method is seen as valuable for several reasons:

1. It requires less instructional time and can be added to the current curriculum more easily.

2. It fits the teaching style of many teachers.

3. It requires fewer material resources than a lab-activity based approach.

4. Time remaining at the end of class which is normally wasted could be made productive in teaching process skills.

A secondary question investigated was the possibility of any differences in process skill achievement due to gender. A review of almost 300 research studies by Malone and Fleming (1983)

concluded that boys showed greater science achievement than girls. The greatest differences appeared in middle school students (.32 positive effect size); the difference in high school students was only +.15. A literature review by Maccoby and Jacklin (1974) found that females excel in verbal abilities while males excel in mathematical and spatial abilities. Because process skills involve verbal as well as mathematical and spatial abilities and because of the relatively small gender differences in science achievement found at the high school level, a significant gender difference in process skill achievement was not expected.

Method

Subjects

Two tenth-grade advanced first-year Biology classes at a Forsyth County, Georgia high school were randomly selected for the study. The students had been assigned to the advanced classes based on their previous science grades and recommendations of their junior high science teachers. Assignment to a particular section of advanced Biology is done by a computer and is essentially random except for maintaining some balance between the sexes and total class sizes. From three sections of Advanced Biology taught by one teacher, one class was randomly selected to receive the treatment and a second class was selected as a control group.

Research Design

The experiment was conducted over a three week period. The research design using Campbell and Stanley's (1963) notation was as follows:

O_1 X_1 O_2 O_3

O_1 X_2 O_2 O_3

TREATMENT: X_1 = Process Skills and Content Instruction

X_2 = Control, Content Only Instruction

MEASURES: O_1 = Previous six-weeks grade

O_2 = MIPT test

O_3 = Current six-weeks grade

Treatment

The treatment consisted of the presentation of 23 process skills lessons. The lessons were designed to cover each of the eight basic and six integrated process skills as listed in the Science - A Process Approach curriculum AAAS, 1965. Some of the skills were covered by several lessons. The lessons were of three types. Most were overhead transparencies (13 of the 23), six were process skill worksheets designed to be handed out to the students, and two were labs. A list of each lesson, the process skills taught, and the time required for completion is given in Table I.

The overhead transparencies were designed to involve the students in identifying and practicing a process skill or group of skills. For example, a transparency involving the skills of observing and classifying presented a group of symbols identified as "barfs" and a different but similar group identified as "not barfs." A third group of symbols was then presented and the students were challenged to pick out the barfs from the non-barfs. One transparency could be presented in just a few minutes of class time. Several transparencies might be presented in one day depending on time available. Time remaining at the end of

TABLE I

Process Skills Curriculum Materials

Number	Type*	Process Skill	Time
0	OHT	All	10 min. at beginning of unit & when new skills are introduced
1	OHT	Observing	2 min
2	OHT	Classifying	2 min
3	OHT	Observing, Classifying, Predicting	5 min
4,5,6	OHT	Observing, Classifying	2 min each
7	PSG	Observing, Classifying	15 min
8	PSG	Observing, Classifying, Using key	15 min
9	OHT	Space/Time	2 min
10	OHT	Space/Time	10 min
11	PSG	Space/Time, Observing Predicting, Formulating Models	20 min
12	PSG	Using Numbers (Metric & scientific notation)	30 min
13	OHT	Space/Time, Inferring Interpreting Data	2 min
14	OHT	Steps in scientific method	5 min + review before labs
15	OHT	Formulating hypotheses	10 min
16	OHT	Identifying & Controlling variables	5 min + review
17	PSG	Identifying hypotheses & variables	30 min
18	OHT	Defining Operationally	10 min
19	PSG	Using Numbers, Space/Time, Communicating, Interpreting Data	30 min
20	OHT	Experimenting	10 min Give copy to each student.
21	LAB	Using Numbers, Metric system	50 min
22	LAB	Experimenting, All skills	5 min per day for 2 weeks

* OHT= overhead transparency PSG= Process skills guide handout

class after the normal content material had been covered was thus made productive in teaching process skills.

The process skills worksheets required more time than the transparencies (15+ minutes) and thus were used when more extra time was available or were assigned for homework. The two labs required even more time: one on metric measurement took an entire class period and the other giving practice in observation, forming hypotheses, and designing experiments required about five minutes each day over a two week period. Copies of a sample overhead transparency, worksheet, and lab are contained in the Appendix.

The treatment group received the same content instruction as the control group. Since the process skills instruction required so little class time, it could be presented without eliminating any of the standard curriculum. The control group received the normal content instruction. When the treatment group was doing the metric lab which required an entire class period, the control group did a traditional-style lab that was not normally in the curriculum.

Instruments

All subjects were post-tested with the Middle Grades Integrated Science Process Skills Test (MIPT) (Padilla and Cronin, 1986). Field tests of the MIPT with 1152 seventh grade science students have demonstrated its reliability (KR 20 = .89) and validity (Cronin and Padilla, 1986). The advantage of the MIPT over other integrated process skills tests (e.g., TIPS) is that the MIPT is specifically designed to be content free and to

have a relatively low readability level (average grade level FOG index = 6.1). The test consists of 40 multiple choice items and was completed by the students in 30 minutes or less.

Two additional measurements were recorded for use in analysis of the study. The preceding six-weeks grade for each student was used as a covariate in an analysis of covariance (ANCOVA) procedure. The six-weeks grade for the grading period during which the experiment was conducted was used as a post measure of biology content achievement. The purpose of the content post measure was to test the hypothesis that content achievement of the treatment group will not decline because of the class time spent on process skills development rather than content instruction. Six-weeks grades were determined by averaging all grades on teacher-made tests, homework, reports, and other activities during that grading period.

Data Analysis

The data related to the research hypotheses were analyzed using a 2 X 2 (treatment by gender) fixed factor design. Main effects and interactions were analyzed simultaneously using analysis of covariance (ANCOVA) procedures with the previous six-weeks grade as the covariate. Separate two-way ANCOVAs were performed on each of the dependent variables (MIPT scores and current six-weeks grades).

Results

Descriptive statistics for all measures are presented in Tables II - IV. Table II presents the means of the previous six-weeks grades which were used as the covariate in the ANCOVA. Males and females in the treatment group differed in these

TABLE II

Previous Six-weeks Grades by Sex for Both Groups

Group	Sex	n	M	SD
Treatment	Male	14	87.29	8.53
	Female	14	81.29	13.14
	All	28	84.29	11.29
Control	Male	13	88.54	5.74
	Female	16	87.19	5.42
	All	29	87.79	5.51

initial scores by more than the sexes in the control group, but neither of these differences was statistically significant (p=.16 for treatment and p=.52 for control). The overall effect of adjusting the means of the post measures using the previous six-weeks grades as the covariate was to slightly raise the means of the treatment group and lower the control group means on both post measures (Tables III and IV).

TABLE III

MIPT Scores by Sex for Both Groups

Group	Sex	n	M	Adj.Mean
Treatment	Male	14	29.21	28.81
	Female	14	26.57	27.94
	All	28	27.89	28.38
Control	Male	12	23.75	23.02
	Female	15	23.60	23.28
	All	27	23.67	23.15

Results of the ANCOVA hypotheses tests for each dependent variable are reported in Tables V and VI. The treatment group scored significantly higher than the control group on the MIPT measure of process skills ability (p=.004). No significant differences were found between sexes nor were there treatment-sex interactions.

TABLE IV

Current Six-weeks Grades by Sex for Both Groups

Group	Sex	n	M	Adj.Mean
Treatment	Male	14	83.00	81.81
	Female	14	80.21	84.91
	All	28	81.61	83.36
Control	Male	13	84.92	82.50
	Female	16	83.56	82.47
	All	29	84.17	82.48

TABLE V

Analysis of Covariance Summary

Dependent Variable = MIPT

Source	df	Type III SS	F	p
Covariate	1	347.48	8.98	0.004
Treatment	1	358.57	9.27	0.004
Sex	1	1.22	0.03	0.86
Treatment*Sex	1	4.39	0.11	0.74

Covariate = Previous six-weeks grade

TABLE VI

Analysis of Covariance Summary

Dependent Variable = Current Six-weeks Grade

Source	df	Type III SS	F	p
Covariate	1	3877.98	60.94	0.0001
Treatment	1	10.39	0.16	0.69
Sex	1	31.85	0.50	0.48
Treatment*Sex	1	34.23	0.54	0.47

Covariate = Previous six-weeks grade

No significant differences were revealed between the treatment and control groups in their current six-weeks grades ($p=.69$). Differences due to sex or treatment-sex interaction were also non-significant.

Discussion

The results of this experiment are based on a comparison of only two classes after a treatment period of three weeks. Any conclusions must be considered tentative until replications of the experiment have provided additional support. Based on this study, however, the experimental results clearly indicate that process skills can be successfully taught by the lecture-class discussion method. Students who were introduced to process skills by this method showed increased understanding of process skills with no loss of content achievement. Teachers who would prefer this method because of considerations of time, teaching style, or equipment limitations, are encouraged to add process skills instruction to their curriculum.

An additional advantage of the method introduced in this study is that it may be integrated into the curriculum. Practice with process skills need not be limited to a two week unit of instruction and then forgotten. The individual overhead transparencies and brief activity guides may be used at any appropriate time throughout the school year. Skills which students have not mastered may easily be reviewed.

The lecture-class discussion method of teaching process skills is not seen as a replacement for process skills labs. The major benefit of this method is in introducing process skills

instruction into a curriculum where it does not currently exist. Once instruction in process skills becomes a part of the curriculum, then teachers are encouraged to develop process skills labs. Padilla, Okey, and Garrard (1984) have provided a useful model for developing labs that give students practice in using process skills. The experiences of these authors, Shaw (1983), and others have shown that activity-based process skills instruction is effective in promoting process skills achievement. Whether or not the treatment evaluated in this paper could more effectively or efficiently provide process skills instruction would be an interesting question for further investigation.

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APPENDIX

PROCESS SKILLS

Skills: Defining Operationally

OPERATIONAL DEFINITION = A WORKING DEFINITION SUITED TO A PARTICULAR EXPERIMENT

WHAT IS WRONG WITH THE FOLLOWING EXPERIMENTAL RESULTS?

1. THE PLANTS DID BETTER WITH THE NEW FERTILIZER.

2. THE DETERGENT CLEANED CLOTHES CLEANER.

3. CANNED DOG FOOD IS BETTER FOR DOGS THAN DRY DOG FOOD.

THE ABOVE EXPERIMENTS LACK A CLEAR OPERATIONAL DEFINITION OF THE DEPENDENT VARIABLES.

FOR EACH OF THE FOLLOWING VARIABLES GIVE TWO DIFFERENT SPECIFIC OPERATIONAL DEFINITIONS. TELL HOW YOU COULD MEASURE THE VARIABLE AND WHAT UNITS YOU WOULD USE FOR THE MEASUREMENT.

DEPENDENT VARIABLE	OPERATIONAL DEFINITION	HOW MEASURED	UNITS
GROWTH OF PLANTS			
YIELD FROM TOMATO PLANTS			
EFFECTIVENESS OF BUG SPRAY			
EFFECTIVENESS OF A LEARNING TECHNIQUE			

PROCESS SKILLS GUIDE: IDENTIFYING HYPOTHESES AND VARIABLES

Susan's family had two Mustang convertibles. The cars were identical except that one was red and one was green. Susan thought that people noticed her more when she drove the red Mustang than when she drove the green Mustang. She tested her impression by counting the number of times someone honked or waved at her when she was in each car. She was careful to drive each car the same amount of time on the same route on alternate nights. After six days she totaled the number of times people had noticed her in each of the cars. Her data looked like this:

DAY	CAR COLOR	NUMBER OF HONKS OR WAVES
SUN	RED	6
MON	GREEN	4
TUE	RED	7
WED	GREEN	5
THUR	RED	7
FRI	GREEN	13

Answer these questions about Susan's experiment:

1. What is her hypothesis?

2. What is the independent variable in her experiment?

3. What is the dependent variable?

4. What are the controlled variables?

5. Do the data support Susan's hypothesis?

6. Were there any flaws in her experimental method? Explain.

PROCESS SKILLS LAB: LIFE?

PURPOSE:
1. To gain practice in careful observation, forming hypotheses, and designing experiments
2. To discover some of the characteristics of life

MATERIALS: bottle of unknown material, magnifying glass or dissecting microscope

PROCEDURE: Without removing the stopper, observe the bottle of material a few minutes each day for two weeks. Keep a record of your daily observations. (See Results section of Lab.)
Answer the following questions based on your observations. (Write your answers in the RESULTS section of your lab report.)

1. Do you think there is any life in the bottle? Write an hypothesis that you could test to confirm your answer about life in the bottle.
2. Is there evidence of life in the bottle at the beginning of the experiment?
3. List as many things as you can observe which indicate that there is or is not life in your bottle.
4. Is there any evidence of death in the bottle?
5. Why do you think there is or is not death?
6. At what point did evidence of life first appear?
7. Where could the living things have come from?
8. How many different kinds of living things do you observe?
9. How many individual living things can you see each day? (Organize this data in a table and then graph the data.)
10. What evidence of change over a period of time do you observe?
11. List and describe each stage in the life cycle of any living things you observe in the bottle.
12. Can you tell any difference in the sex of any living things in the bottle?
13. Based on your observations over two weeks, develop a hypothesis to explain:
    1. where the living things came from
    2. how many living things were in the bottle before you began your observations
    3. how long these living things can stay alive in the bottle
14. Design a short experiment that would support or disprove one of your hypotheses. Include controls so that you can eliminate influences on your experiment other that those which you are testing. Write up your experiment in the proper form including a statement of your Problem, Hypothesis, and Variables (independent, dependent, and controlled.) List the Materials you would need and describe your experimental Procedure.

RESULTS: (Keep a record of your observations in this section of your Lab Report. Write the date of your observation, any special conditions present which might affect your experiment, and your observation.

Example: 5 Sept. 1988 - air conditioner not working, temp. 90 °F, 5mm water standing on top of substance in bottle, no sign of movement, no other changes

Whenever possible, organize your observations in the form of a table or graph. Every graph should include these parts: Title, label for the horizontal axis, label for the verticle axis. For these data it is appropriate to begin numbering each axis at 0. Choose a uniform scale for each axis that is large enough to include your complete range of data.)

CONCLUSIONS:

1. Do your results support your hypothesis as stated in question 1 ?
2. Which data specifically support or disprove your hypothesis?